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Economic Impact of EPA's Regulations on the Petroleum Refining Industry Volume 1. Executive Summary

Sobotka and Co., Inc.

Prepared For
Environmental Protection Agency

April 1976

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ECONOMIC IMPACT OF EPA'S REGULATIONS ON THE PETROLEUM REFINING INDUSTRY

Executive Summary

APRIL 1976

FINAL REPORT

Contract No. 68-01-2830

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Planning and Evaluation
Washington, D. C. 20460

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16. Abstracts

Study examines the economic impact of EPA regulations 1974-83 on petroleum refiners. The regulations taken into account were air emissions, water effluent standards, and product quality (lead in gasoline and residual fuel oil desulfurization). Under the assumptions that (1) price controls will lapse according to the currently legislated schedule and that, (2) consistent with current U.S. policy, continued tariff protection adequate to insure the growth of petroleum product consumption in the U.S. will be furnished U.S. refineries, the economic impacts were found to be slight. Volume 1 is the Executive Summary, Vol. 2 is an Industry Description and Technical Analysis, and Vol. 3 is the Economic Impact Analysis

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PREFACE

This report is the result of a major program of studies sponsored by the Environmental Protection Agency as part of its continuing effort to assess the economic impacts of its regulatory programs. Unlike many of EPA's other industry economic studies where the focus is on the impact of a particular regulation, this study was aimed at examining the combined effect during the period 1974-83 of all of EPA's direct regulatory programs on the Petroleum Refining Industry.

In addition to providing an assessment of the combined impact of EPA's regulatory programs, a major objective of this study was to advance the methodologies used in previous studies of petroleum refining so as to provide more accurate conclusions as well as provide a better foundation for future studies. It is believed that such an advance has been achieved.

In sponsoring this study, the EPA wanted to make an independent assessment of the Petroleum Refining Industry. Although the overall conclusions are endorsed by the Agency, there may be instances in which technical judgments of the contractor differ from those of the EPA. Similarly, assumptions used in the study that are of a policy nature should not be construed as an indication of EPA policy intentions.

This report was prepared for EPA by Sobotka and Company, Inc. of Stamford, Connecticut under contract number 68-01-2830. Additional copies are availabe through the National Technical Information Service, Springfield, Virginia 22151. Further information concerning this and other economic studies conducted by EPA can be obtained through the Office of Planning and Evaluation, U.S. Environmental Protection Agency.

AN ANALYSIS OF THE ECONOMIC IMPACT OF EPA'S REGULATIONS ON THE PETROLEUM REFINING INDUSTRY

EXECUTIVE SUMMARY

ABSTRACT

Consumption of petroleum products in the U.S. is forecast to be larger in 1983 than it now is. Growth will be supplied by expanding the U.S. petroleum refining industry. During the nine-year period 1974 to 1983 the industry will experience the following impacts from EPA's regulations, relative to the status that existed in 1973:

Expansions will require capital investments of 1.1 billion dollars to meet EPA's regulations. Annual costs, including capital charges, will be about 0.5 billion dollars per year all of which will be recovered via price increases averaging about one cent per gallon of product manufactured.

Refinery capacity that existed in 1973 will be required to invest 4.8 billion dollars to meet EPA's regulations. Annual cost to these plants will increase by about 1.4 billion dollars per year. But the price change associated with EPA's regulations for refinery expansion will, by 1983, increase the sales revenue of existing-in-1973 capacity by 2.0 billion dollars. This net improvement in cash flow reflects the large investment to meet EPA's regulations already made in existing refineries, most of which is not now being recovered.

No existing refineries are expected to be forced out of business solely by EPA's regulations.

EXECUTIVE SUMMARY

I. Introduction

The economic well-being of the petroleum refining industry is influenced by United States and foreign government policies unrelated to environmental considerations. These policies have been in a state of flux for some years.

Until fairly recently, the output of the refining industry had grown at a steady rate. This would not have happened in the absence of economic incentives necessary to attract capital to the industry. As long as normal market incentives prevailed, the viability of firms within the industry was governed by their relative economic efficiency. With the imposition of price controls, and mandatory product and crude oil allocations, normal economic incentives ceased functioning. Also the Congress is now considering legislation which would significantly restrict petroleum companies' allowed areas of operations. For example, proposals which would prohibit crude oil producers from marketing oil products have been made.

It is not within the scope of this project to discuss the desirability of the non-market rules now in effect. However, it is necessary to point out that their economic impact is very large. For example, a refiner who, under the current crude oil entitlement program, is granted a substantially larger quota of lower priced "old" crude oil than he would be able to purchase on the open market is given a great deal of assistance by government. On the other hand, a refiner who, because of price controls, cannot charge market clearing prices - even if the effect of price controls is to hold average prices only a few percentage points below equilibrium levels - may have his income reduced substantially below the levels that would prevail in a free market.

If the industry as a whole is growing, and capital is being invested in new or growth facilities, then it is reasonable to expect that aggregate product prices (and hence, refiner's margins) will be sufficiently high to attract capital to the industry. In this case there will be returns earned at least on that portion of environmental capital associated with growth. Because the prices of industry products from new or existing facilities are indistinguishable, the prices will then also be high enough to defray the costs of environmental capital expenditures on existing facilities to the extent that they do not exceed the per unit costs in new facilities.

However, if the industry is not growing and no capital is required for the expansion of existing facilities or the construction of new plants, recovery of the costs of environmental capital presumably will not take place. Under these conditions the bulk of the environmental expenditures to bring existing facilities into conformance with environmental standards would have to be absorbed by the refining industry, which would tend to magnify the economic difficulties of those refiners who already are at a cost disadvantage due to size, location or type of equipment.

This study is limited to assessing the economic impact of pollution abatement costs which result from regulation of petroleum refinery operations; the costs resulting in other activities within the petroleum industry, such as exploration and production, transportation, and marketing, are not within the scope of this study. The impact of limitations on emissions into the atmosphere and into water by refineries, and refinery product quality regulations resulting from EPA regulations are the primary concern. State or local regulations or Federal law (or rules) not based on environmental considerations are excluded from the impact analysis and are considered part of base costs.

The level of emission control used in the study is that envisaged under current and currently-proposed regulations. The base period for the analysis is 1973 operations. Only added impacts in the period 1974-1983 are covered in this study.

II. Industry Operations

The petroleum refining industry in the United States and its possessions consists of some 277 plants, owned by about 139 firms, and located in 40 of the 50 states, Guam, Puerto Rico, and the Virgin Islands. The refineries have a replacement value in excess of 35 billion dollars. The refinery industry employs about 150,000 persons.

The bulk of refining is done by firms which also market refined products or produce crude oil, or do both. In most firms the refining portion of the business is not its major activity. Refinery investment is less than 15 percent of total investment in the domestic oil industry. The industry manufactures hundreds of distinguishably different products which, from the viewpoint of environmental control, may be grouped into four broad product classes: gasoline, middle distillates (often referred to as intermediates), residual, and other.

Foreign, Federal, state and local governments all influence the oil product market. In the recent past, the Federal government's major influence has been through taxes, price controls and tariffs (fees) on imports of crude oil and products. Price controls hold prices down and discourage investment. Foreign crude prices had, until 1973, been lower than domestic, so import rights normally had had considerable value. These rights were allocated among refining firms according to their size. Although large firms had larger quotas than small ones, the latter were given a larger allocation per unit of throughput. Currently,

imports are not quantitatively limited and may be somewhat encouraged by the combination of domestic price controls and the way in which the entitlements to purchase domestic crude oil are allocated.

Government influences the market for petroleum products through imposition of environmental standards. This can take the form of direct specification of product characteristics; e.g., sulfur content in residual oil. Or it may take the form of imposing environmental standards on petroleum product users which affect the nature of the product. For example, control of auto emissions has resulted in a requirement for unleaded gasoline.

1. The Manufacturing Process

In refinery operations certain polluting materials may be released into the environment. The pollutants are by-products of the various refinery processes.

The principal ones arise in operations as follows:

a. Hydrogen sulfide (H_2S) is present in many crude oils and is formed in hydroprocessing (catalytic reforming, hydrotreating, and hydrocracking) and cracking. H_2S is either recovered (and converted to elemental sulfur) or burned. Burning forms sulfur oxides, (primarily SO_2) which are air pollutants.

Sulfur oxides are also formed in the combustion of sulfur-containing liquid refinery fuels. If these fuels also contain nitrogen compounds, the formation of NO_x is enhanced. This NO_x, as well as the small amount of SO_3 formed from sulfur compounds in the fuel, tend to be the principal cause of stack plumes from refinery furnaces.

b. Hydrocarbon vapors can escape from refinery tanks containing crude oil, gasoline, and volatile intermediate products. Other sources of hydrocarbon vapor emissions are tank truck and tank car loading, volatiles unloading facilities, and oil separators in the waste water effluent treating system.

c. Carbon monoxide emission in refineries is essentially confined to flue gases from catalytic cracker regenerators and fluid coker coke heaters.

d. Particulate emission in refineries is significant only from catalytic crackers and fluid cokers (unless coal or coke are used for fuel).

e. Substances which create a biological oxygen demand (BOD) in waste water are formed in catalytic and thermal cracking and in sulfuric acid treatment of petroleum products. Also most of the solvents (phenol, furfural, etc.) used in manufacturing solvent-refined lubricating oils create BOD.

f. Entrained hydrocarbons and dissolved contaminants such as ammonia, light mercaptans and salt (from crude and cooling water treatment) are found in refinery waste water streams. These contaminants may also cause the pH of the water to be outside permissible limits.

Crude oil is by far the most important raw material used by the refining industry. Natural gasoline, a liquid product of the natural gas industry, furnishes about 5 percent of refinery intakes. Butanes contribute about 1.5 percent of refinery intake. There are no other significant raw materials. About 73 percent of industry raw material is of domestic origin; 27 percent is imported.

Oil refineries are categorized by size and by the range of their products. There is also considerable variation in age of

refineries. But additions to and modifications of plants are the industry's principal form of expansion.

The Exhibit on the following page shows the growth of refining capacity and the changes in the number of refineries in the period 1968-1974.

Multiple plant operations are commonplace in the industry. As of December 1, 1974, the 19 largest firms, each of which has a capacity of over 200,000 barrels per day, operated 111 refineries. These 111 plants accounted for 79 percent of the industry's capacity, even though 16 of them had capacities of less than 26,000 barrels per day. Half of all industry refineries (138 plants) are smaller than 26,000 barrels per day. They account for only 8 percent of industry capacity.

Smaller refineries are frequently located within isolated crude producing areas and/or they serve local, moderately-sized marketing areas far from alternate product supply sources.

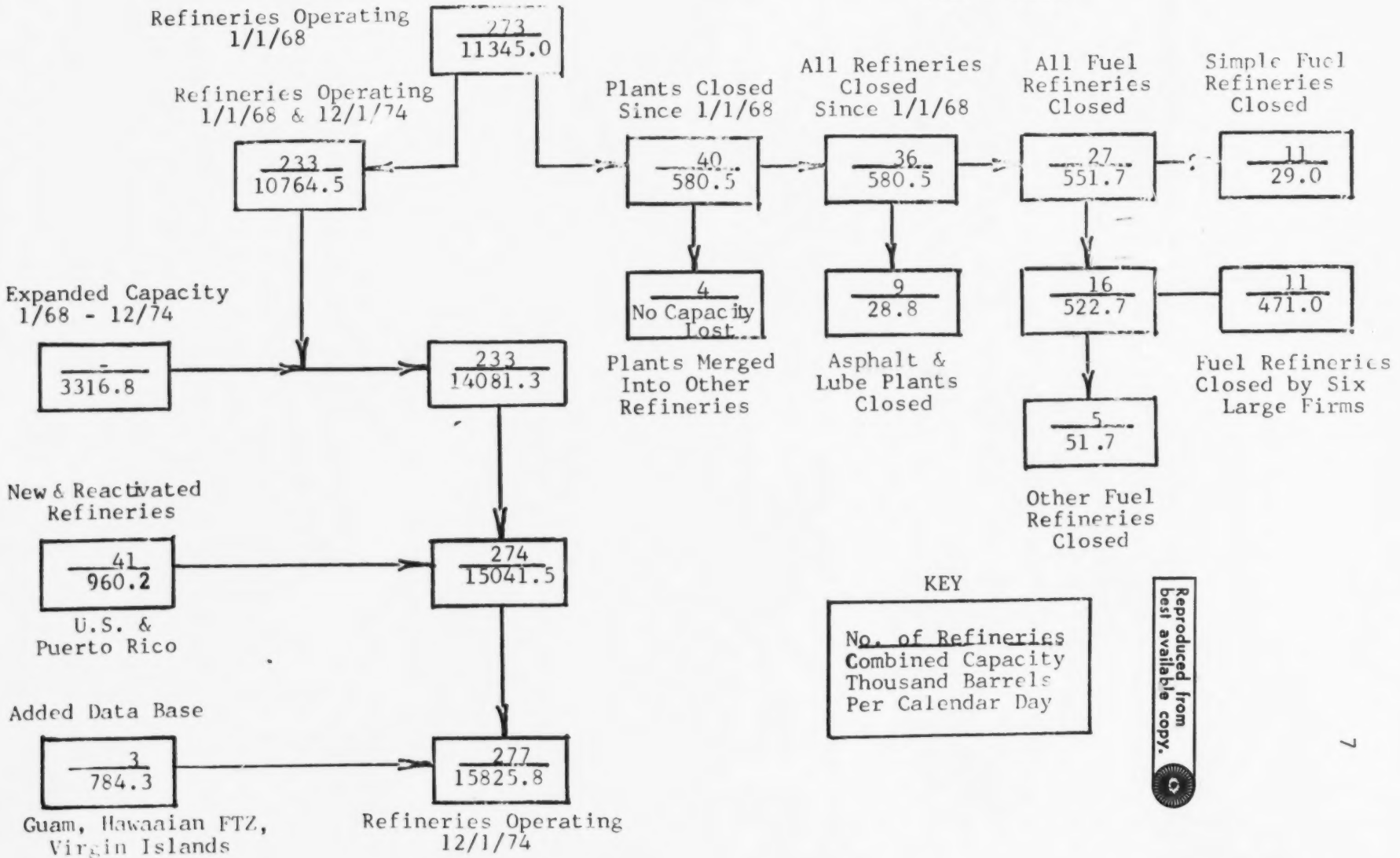
A common technology is used throughout the industry. The differences that do exist are small and probably not significant in terms of a plant's ability to meet environmental standards economically. There are important differences in the extent to which environmental control equipment has been installed to date.

Refinery employment as a whole has been fairly stable. In 1964, there were 150,000 employees and in 1973, 147,000. The imposition of environmental regulations tends to increase this industry's demand for labor.

It is impossible to analyze the financial structure of the petroleum refining industry using published data. Too few firms, and none that are typical of the industry, are exclusively or even primarily in the refining business. No data on refinery

EXHIBIT

Growth of Refining Capacity and C... in Numbers of Refineries 1968 - 1974



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profitability are available. But it is reasonable to assume that in the absence of price controls or product allocations, refining operations are, on the margin, neither more nor less profitable than the rest of a typical oil company's business.

While profitability of the business as a whole has been subject to some variability, industry earnings have been adequate to attract capital to finance growth and replacement.

Due to the uncertainties about future demands, it is impractical to make a detailed estimate of the refining industry's capital requirements for expansion and plant modernization in the years to come. A recapitulation of current industry plans is shown in Part Two and modified in Part Three of this study. In 1973/74, the thirty largest petroleum companies invested about 1.4 billion dollars per year in refineries in the U.S.

Roughly 17 percent of domestic capital expenditures in 1973 by the thirty largest oil companies was for refineries. Total domestic investment in that year for the same group of companies was about 52 percent of worldwide investment.

Were it not for price controls, the domestic market for wholesale oil products would be competitive in the economist's meaning of the term. Prices on the various unbranded markets in the absence of effective price controls typically are close to short-run marginal costs. This indicates that the industry is highly competitive. But price controls have been in effect on domestic products most of the time since 1971.

Prior to the oil embargo, the industry was in transition from a quota system to a tariff system via a price control system. As a result of domestic price control, a significant disparity between world and average domestic prices now exists. And the combination of a three-price crude oil market (new and old domestic, and foreign), with a system of entitlements to purchase "old", lower-priced, crude oil, makes it impossible to generalize about current market conditions. The price control system is slated to terminate in less than four years. Consequently, projections in this study are made on the assumption

that normal competitive market forces will prevail by the end of the period under study (about 1983).

III. Economic Impact of EPA's Regulations

A. Price Effects

1. Methodology

The price analysis rests on two premises: First, the demand for petroleum products in the U.S. will increase during the 1974/1983 period so that new refinery capacity will be required. Second, total growth in U.S. petroleum product consumption will, in keeping with current U.S. policies, be furnished by U.S. refineries.

New refinery capacity will be constructed only if it is economically attractive. That is, the value added by refining must be adequate to pay operating costs and the cost of the capital required for the new capacity. Therefore, the capital required to conform with EPA's regulations in new refineries must earn an adequate return on investment. Existing plants whose EPA costs per unit of output are less than those of new refineries will receive rents. And those with higher EPA costs will absorb those that are in excess of new refineries' costs, or cease operations.

The following price analysis is used: Two "model" versions of refinery expansions will be evaluated. The "base" version is designed to manufacture products demanded in the absence of EPA's post-1973 regulations. Its waterborne and airborne emissions will reflect no post-1973 implementation of regulations. The second ("EPA") version is designed to conform to emission and product quality regulations to be implemented during 1974/1983. The cost differences between these two designs, including return on investment, are the price effects of EPA's regulations. The model chosen for this analysis is designed for a capacity of 123,000 barrels per stream day (about 100,000 barrels processed per calendar day) of 35 degree API light Arabian crude oil. Its product slate exactly meets that part of 1983 U.S. refinery outturn requirements that cannot be met by existing-in-1973 refinery capacity. The yields are:

Product	Percent Yield from Crude Oil
Gasoline	18.8
Kerosene Jet Fuel	15.0
Distillate Fuel Oil	23.3
Residual Fuel Oil	11.1
Petrochemical Feedstocks	14.3
Asphalt	5.5
Other Products	4.7
Internally Consumed	7.3
	100.0

This yield structure is quite different from that normally associated with U.S. refineries. Gasoline yield is much lower while jet fuel, distillate fuel oil and chemical feedstocks are much higher. These differences reflect the effects of the OPEC crude oil price increase and the natural gas shortage on U.S. consumption patterns. The yield structure will be achieved with crude oil distillation, vacuum distillation of atmospheric bottoms, hydrocracking (to intermediates) of vacuum gas oil and catalytic reforming of straight-run naphtha.

Product qualities differ between the two versions of the model in the following respects: 1) Motor gasoline in the base version is leaded 96 research octane number. In the EPA version it is unleaded 92 research octane number; 2) Residual fuel oil in the base version is 1.2 percent sulfur by weight. In the EPA version it is 0.5 percent sulfur; 3) Refinery fuel averages 1.6 percent sulfur in the base version, but 0.7 percent (New Source Performance Standard) in the EPA version.

2. Costs Incurred in Conforming the Base Version of the Model to EPA's Regulations

a. Water effluent control costs are about 22 cents per barrel of crude oil processed.

b. Airborne effluent control costs. In refineries of the size of the model, it is economically attractive to control all hydrocarbon emissions to the atmosphere from storage tanks, waste water treating facilities, and product loading facilities. Consequently, there are no EPA costs for controlling these emissions in the model expansion. Catalytic cracking units emit carbon monoxide and particulate matter, both of which must be controlled. Since there is no catalytic cracking unit in the model, these costs are zero. The base version of the model contains units for desulfurizing naphtha, distillate, vacuum gas oil and atmospheric bottoms. Hydrogen sulfide produced in these units will be collected and converted to sulfur in order not to exceed 1973 SO_x emission limitations. However, Claus plant tailgas cleanup will be required only under EPA's regulations. The cost for cleanup of Claus plant tailgas produced in the base version is 2 cents per barrel of crude oil processed. The EPA version of the model refinery will consume about seven thousand barrels per day of liquid fuel. The cost of desulfurizing this fuel, including the cost of recovering and converting by-product H_2S, is 7 cents per barrel of crude oil processed.

c. Product quality requirement costs. Sulfur content of residual fuel oil must be controlled to a level that will allow its consumers to meet EPA's regulations for SO_x emissions. The allocated cost, including the cost of recovering and converting by-product H_2S, is 8 cents per barrel of crude oil processed.

EPA's regulations on pollutant emissions from gasoline-powered cars and trucks are being met mostly by the installation of catalytic converters on the vehicles. Unleaded gasoline must be used by such vehicles. Other current studies indicate that the savings in lead anti-knock purchase costs will essentially offset the increased capital and associated increased processing costs required for generating higher clear pool octanes. Thus, a net zero refining cost was determined for supplying 92 octane unleaded gasoline in the EPA version of the model in lieu of 96 octane

leaded product. The efficiency loss in vehicles due to lower octane is considered elsewhere in this study.

d. Total EPA costs incurred by the model are summarized below:

EPA Cost Element	Cents per Barrel Crude Oil Processed
Water effluent control	22
Airborne effluent control	
a. Claus plant tailgas cleanup of base version operations	2
b. Refinery fuel desulfurization (1.6 to 0.7 percent sulfur)	7
Product quality requirements	
a. Residual fuel oil desulfurization (1.2 to 0.5 percent sulfur)	8
b. Unleaded motor gasoline	-
TOTAL	39

3. Impact on Prices

The EPA costs summarized in the preceding section will affect petroleum product prices for the period 1974-1983. The costs of water emission control, airborne emission control and desulfurization of refinery fuel are properly allocated to all products. The cost of residual fuel oil desulfurization is necessarily allocated to all products except asphalt.[1)] The cost of manufacturing unleaded gasoline should be allocated to that product only. This leads to the following allocations (on the basis of heating value):

Product	Allocated Costs-Cents per Gallon
Motor Gasoline	1.0
Jet Fuel	1.0
Distillate Fuel Oil	1.1
Residual Fuel Oil	1.1
Asphalt	1.0
All Other Products	1.1

1) The reasoning underlying this conclusion is developed in Section C. of Chapter II.

These costs will all be passed forward to consumers as price increases. Since weighted average consumer price for petroleum products in 1983 will be on the order of 45 cents per gallon (1974 prices), the average price increase faced by consumers as a result of EPA's regulations will be about two percent.

4. Disposition of EPA Costs

a. Crude oil absorption. One might argue that a portion of the costs of EPA's regulations will be absorbed by crude oil producers in order that their markets grow as rapidly as they would in the absence of EPA costs. Two markets must be considered. First, foreign producers will be the source of the crude oil displaced by EPA's regulations. It is impractical for foreign suppliers of crude oil to discriminate between U.S. and other customers. So it would be unattractive for foreign producers to cut world prices to attempt to recoup the small volume lost in the U.S. as a result of EPA costs. Hence, no pass-back of the cost of EPA's regulations to foreign suppliers of crude oil should be expected. Second, supplies of domestic crude oil will fall well short of the intake of U.S. refineries so its price will be determined by the price of imported crude oil (or by price controls). Consequently, no significant EPA cost pass-back to domestic crude oil producers is likely.

b. Foreign refining competition. Consistent with U.S. energy policy, this entire analysis rests on the assumption of tariff (or quota) protection adequate to insure that the total growth of petroleum product consumption in the U.S. will be furnished by new U.S. refineries. Consequently, foreign refining competition has been "defined away." The extent of protection required to validate this assumption is discussed later in the report.

c. Inter-fuel competition. With the exception of transportation fuels, petroleum products compete with other energy sources in all applications. Over the period of this study it is

clear that neither natural gas, nuclear energy, solar energy, hydroelectricity, nor geothermal power will be marginally available to compete with oil. Consequently, only coal (including electricity generated from coal), need be considered. Should coal competition materialize, the oil product price structure will adjust as it has in the past. That is, the price of residual fuel oil will fall below the price of crude oil, and other products will increase commensurately. (Necessarily, the weighted average price for products must be attractive if new refineries are to be built.) As a practical matter, enough residual fuel oil is imported into the U.S. that imports would be expected to bear the brunt of coal competition. The resource cost of domestic coal, including environmental costs, is equivalent to about half of the cartel price for residual fuel oil. The cartel could not compete without disrupting itself. So oil prices would be largely unchanged by coal competition, but volume would drop as coal became available.

B. Impact of EPA's Regulations on Sales and Output of Petroleum Refineries

1. Consumer prices in the absence of EPA's regulations are estimated to be as follows:

Product	Percent Of Model Expansion Outturn	Refinery Gate Price In Base Version Of Model Expansion (Cents Per Gallon)	Consumer Price (Cents Per Gallon)
Motor Gasoline	20.3	38	63
Jet Fuel	16.2	36	39
Distillate Fuel Oil	25.1	36	44
Residual Fuel Oil	12.0	36	38
Asphalt	5.9	32	35
Other Products (all low sulfur)	20.5	36	39
	100.0		

2. Estimates of product volumes in 1985 in the absence of EPA's regulations are as follows:

Product	Forecast Domestic 1985 Consumption (Million Barrels Per Day)
Motor Gasoline	7.27
Jet Fuel (Kerosene Range)	1.52
Distillate Fuel Oil (including Kerosene)	3.79
Residual Fuel Oil	3.09
Asphalt	0.73
Other Products (all low sulfur)	1.77

3. Volume effects of EPA's regulations are estimated to be as follows:

Effect of EPA's Regulations
On Petroleum Product Consumption
In the United States In 1985

Product	Percent	Million Barrels Per Day
Gasoline	+ .7	+.051
Jet Fuel	- .3	-.004
Distillate Fuel Oil	-1.5	-.057
Residual Fuel Oil	-2.5	-.077
Asphalt	- .3	-.002
Other Products	-1.9	-.034
Total		-.123

4. Sulfur Recovery and Lead Usage Changes

Refineries will recover about 1.1 million tons of sulfur as a result of EPA's regulations. This quantity represents a small part of the United States' sulfur production which in 1971 was about 120 million tons. This, in turn, was about 42 percent of world output.

In 1973 the petroleum refining industry purchased about 959 million pounds of lead anti-knock compound valued at about 519 million dollars or 54 cents per pound. This amount of anti-knock compound contained roughly 180 thousand short tons of lead. By 1983 the purchases of lead for anti-knock compound manufacture will be reduced to about 63 thousand tons (if the lead reduction schedule is in effect) or to about 117 thousand tons (if no such schedule is in effect but new automobiles require unleaded gasoline). Annual lead production in the U.S. is roughly 600 thousand short tons and this represents only about 15 percent of world production. Thus, the reduction in the use of lead by the refining industry implies a reduction in demand of up to about a fifth of current U.S. production, or about three percent of world production.

C. Aggregate Industry Impacts

1. Capital Requirements

The gross requirements for capital to meet EPA's regulations over the period 1974 to 1983 is about 6.3 billion dollars (0.7 billion dollars per year on average). Offsetting this is a capital requirements reduction of about 0.4 billion dollars to account for new refinery capacity that would not need to be built because product demands with EPA's regulations are lower than without them. This 0.4 billion dollar reduction should not be viewed as a decrease in the impact of EPA's regulations, or as resulting in an improvement in social welfare due to a lessening in the demands for capital. The net 5.9 billion dollar capital cost of conforming to EPA's regulations represents roughly 1/6 of the replacement value of the domestic petroleum refining industry. Capital expenditures for U.S. refineries in 1973/74 averaged 1.4 billion dollars per year. Total 1974 capital expenditures for the domestic integrated oil industry (including exploration, production, refineries, transportation, distribution and marketing) were 16.6 billion dollars.

2. Impact on Growth of Refining Capacity

The combined effects of EPA regulations is to decrease new refinery capacity requirements by 33 thousand barrels per stream day. The investment cost for new refinery capacity is about 2,500 dollars per daily barrel of crude oil processing capacity. Hence, the investment requirements for new capacity will be reduced as a result of EPA's regulations by a net of 83 million dollars. This cost savings is the net of a 330 million dollar cost increase for energy manufacturing facilities needed to run EPA installations less a 413 million dollar cost decrease because fewer products will be demanded due to EPA-caused higher prices.

3. Capital Needs and Annual Costs

a. Water effluent control costs are:

	Cost - Million Dollars	
	Capital	Annual*
Existing-in-1973 Capacity		
Period 1974 thru 1977	1,610	617
Period 1978 thru 1983	553	834
New-after-1973 Capacity		
Period 1974 thru 1977	217	111
Period 1977 thru 1983	286	230
	2,666	1,064

* Operating costs plus capital charges in last year of period indicated.

b. Airborne emission control costs are:

For hydrocarbon emission control from tanks, loading racks and API separators -

	Cost - Million Dollars	
	Capital	Annual
Existing-in-1973 Capacity		
Period 1974 thru 1977	43	6
Period 1978 thru 1983	11	7
New-after-1973 Capacity		
Period 1974 thru 1977	-	-
Period 1978 thru 1983	-	-
	54	7

For control of emissions from catalytic cracking units -

	Cost - Million Dollars	
	Capital	Annual
Existing-in-1973 Capacity		
Period 1974 thru 1977	127	39
Period 1978 thru 1983	32	49
New-after-1973 Capacity		
Period 1974 thru 1977	6	2
Period 1978 thru 1983	-	2
	165	51

For control of sulfur oxide emissions from petroleum refineries -

	Cost - Million Dollars	
	Capital	Annual
Existing-in-1973 Capacity		
Period 1974 thru 1977	303	100
Period 1978 thru 1983	117	144
New-after-1973 Capacity		
Period 1974 thru 1977	190	85
Period 1978 thru 1983	57	110
	667	254

c. Product quality requirements. The total costs for U.S. refineries to meet EPA's regulations for the sulfur content of residual fuel oil are:

	Cost - Million Dollars	
	Capital	Annual
Existing-in-1973 Capacity		
Period 1974 thru 1977	79	36
Period 1978 thru 1983	79	73
New-after-1973 Capacity		
Period 1974 thru 1977	175	86
Period 1978 thru 1983	52	111
	385	184

For the manufacture of unleaded gasoline, and lead phasedown -

	Cost - Million Dollars	
	Capital	Annual
Existing-in-1973 Capacity		
Period 1974 thru 1977	1,091	107
Period 1978 thru 1983	759	303
New-after-1973 Capacity		
Period 1974 thru 1977	120	-
Period 1978 thru 1983	36	-
	2,006	303

Note: As stated elsewhere in this study, lead regulations do not impact the annual cost and price of gasoline in new capacity. But the above capital costs are real (even in new capacity) because they would not be incurred in the absence of a requirement for unleaded gasoline.

d. The total costs of EPA's petroleum refining industry regulations are:

	Cost - Million Dollars Capital	Annual
Existing-in-1973 Capacity		
Period 1974 thru 1977	3,253	905
Period 1978 thru 1983	1,551	1,410
New-after-1973 Capacity		
Period 1974 thru 1977	708	284
Period 1978 thru 1983	431	453
	6,273[1)]	1,863

4. Recovery and Absorption of EPA's Costs

To the extent that unit costs of conforming an existing refinery to EPA's regulations are less than the costs of conforming new refineries, the price increases that will occur will create economic rent for the plant. Conversely, if existing plant costs are greater than those for new capacity, the existing plant capital value will decline by the extent of the difference. New refinery capacity will be neither advantaged nor disadvantaged by having to conform to EPA's regulations. This is so because new refineries will only be built if the product price structure fully reflects EPA costs.

The amount of EPA costs recovered by exis ing refineries will equal the volume of products manufactured in these plants in 1983 times the price increase caused by EPA's regulations. With one exception, existing refineries will observe the same product price increases as were derived for expansions. The exception is residual fuel oil. The higher sulfur content

1) Includes 330 million dollars for facilities to provide energy to operate EPA installations.

residual fuel oil manufactured in 1983 in existing-in-1973 refineries will sell for fifty cents per barrel less than the low-sulfur product manufactured in expansions.

Recovery of EPA costs is:

Recovery of EPA Costs by Existing-in-1973 Refineries

	Product Outturn In 1983 (Million Barrels)	EPA Price Increase	
		Dollars Per Barrel	Million Dollars Per Year
Gasoline	2,379	0.42	1,000
Kerosene Jet Fuel	317	0.42	133
Distillate Fuel Oil	1,012	0.46	466
Residual Fuel Oil	384	(0.04)	(15)
Asphalt	188	0.42	79
All Other Marketed Products	717	0.46	330
Total	4,997		1,993

The difference between this cost recovery and the annual EPA cost in 1983 of existing-in-1973 refineries is a (1.993 - 1.410 =) 0.6 billion dollars per year gain. That is, cash flow before tax for these plants will increase by 0.6 billion dollars per year, or about 11 cents per barrel crude oil processed. The EPA impact on existing-in-1973 refineries is a gain because the cost of conforming to EPA's regulations in these plants is, on average, less than it is in new capacity.

Capital expenditures in the U.S. during the 1974/1983 period will average roughly 150 billion dollars per year. Compared to this the net capital requirements for conforming the petroleum refining industry to EPA's regulations (0.7 billion dollars per year) is trivially small. The reader is, however, referred to a study of the construction industry[1)] for a thorough discussion of

1) Stephen Sobotka & Company, The Economic Impact on the Construction Industry of Additional Demand Caused by New Environmental Protection Standards, EPA Contract No. 68-01-0554, December 29, 1972

the distributive effects of capital demands placed both on the capital markets and on the construction industry by EPA's regulations for all industry and Government.

Implementation of EPA's regulations will increase employment in the petroleum refining industry relative to the level that would have obtained in the absence of EPA. Operators and maintenance personnel will be required for effluent treating facilities and new desulfurization and catalytic reforming units. Offsetting this will be a reduced need for employees in new plants. Employment of production and related workers in refineries in 1973 was about 89,000. Replacement value of the 1973 industry (in 1974 dollars) was roughly 39 billion dollars. Net capital requirements over the 1974/1983 period to meet EPA's regulations are six billion dollars. A first approximation, then, of the employment increase associated with the implementation of EPA's regulations on the petroleum refining industry is:

$$89 \times \frac{6}{39} = 14 \text{ thousand employees}$$

This is a highly uncertain forecast because no allowance is made for technological improvements. Nevertheless, there is no doubt that implementation of EPA's regulations in this industry will lead to employment increases over the levels that would otherwise prevail.

D. Differential Impacts Due to Refinery Size and Configuration

In Section A the impact of EPA's regulations on the cost structure of a model refinery expansion was presented. It was shown there that the annual cost increases resulting from EPA's regulations will be about 39 cents per barrel of crude oil in 1983. For capacity expansions of the type that will set industry prices in the period under study this cost increase will be exactly recovered by product price increases.

In the preceding section the impact of EPA's costs on the aggregate value of the existing-in-1973 refining industry was presented. It was concluded that, on average, the capital value of the industry was slightly enhanced by EPA's regulations.

1. Study Coverage and Methodology

89 of the smallest refineries were examined in greater detail to determine if any of these plants will be sufficiently impaired to prejudice their viability. This segment includes all but eleven of the plants with less than 20,000 barrels per day of capacity. Because it was concluded that there would be no aggregate industry capital impairment, there was no need to investigate the larger, more viable, segment of the refining industry in detail.

EPA's regulations will impact existing small refineries in two ways. The refineries will face expenditures to conform with EPA's regulations. Offsetting this, however, will be the product price increases presented in Section A above. The analysis of small refineries, then, will consist of determining the net of EPA costs and EPA-induced price increases for each small plant. The net cost (benefit) for each plant will then be compared against the cash income before tax that would be earned by the plant in the absence of EPA's regulations. If EPA net cost exceeds cash income before tax, the plant will most probably have to shut down. Conversely, if EPA cost is less than cash flows, the plant will clearly have an economic incentive to continue operation.

2. Net EPA Costs for the Small Refineries

A series of prototype model refineries was defined so that the effects of processing configuration and capacity on EPA costs could be determined. The following processing configuration classifications were considered:

"T"-type - topping plants processing low-sulfur crude oils into low-sulfur residual and distillate fuel oils, and naphtha jet fuel.

"A"-type - topping plus vacuum distillation to process high-sulfur crude oils into asphalt, high-sulfur distillates, and naphtha jet fuel.

"R"-type - topping plus catalytic reforming to process low-sulfur crude oils into gasoline and low-sulfur fuel oils.

"C"-type - topping plus catalytic reforming plus cracking (catalytic, hydro or thermal) to process low-sulfur crude oils into gasoline and low-sulfur fuel oils.

Processing capacities of 2.0, 6.0 and 18.0 thousand barrels per day were considered.

The 89 small refineries for which water effluent flow rates were available were each assigned to one of the prototype classes. There are 28 "T"-type topping plants; 20 "A"-type asphalt plants; 19 "R"-type reforming plants and 22 "C"-type plants containing cracking facilities (14 catalytic, 6 thermal cracking and/or coking, 2 hydrocracking). Product yield structure and crude type for each class were assumed to be identical to those derived for the prototypes. This assumption determined the air emission control and product quality requirements (unleaded gasoline and low-sulfur residual fuel oil) for each refinery. Size-dependent annual costs for conforming to these regulations were assigned to each refinery on the basis of the prototype studies. Water effluent control costs were assigned to each refinery based on actual 1973 water effluent flow rate and the (flow-dependent) costs of conforming the quality and quantity of this effluent to EPA's regulations.

The higher costs (relative to high-sulfur crude oils) of the low-sulfur crude oils needed by existing small U.S. refineries to meet 1973 product sulfur requirements are not costs assignable to EPA's regulations because sulfur-dependent crude oil price differentials will develop in the world market (from sulfur oxide limitations imposed by European and Japanese environmental protection authorities) independent of actions taken by the United States EPA. And world crude price differentials will determine the differentials paid by U.S. refineries.

Small refinery prototype processing configurations "T", "R", and "C" were premised to utilize low-sulfur grades of crude oil to meet 1973 product quality requirements. This is a rational premise, because the historical price differentials between high- and low-sulfur crude oils were generally too small to justify the high unit cost of installing corrosion-resistant metallurgy and product desulfurization facilities in small refineries. Also most small refineries are so located that they have good access to (formerly plentiful) U.S. low-sulfur crude oil supplies. In order to meet 1983 regulations small U.S. refineries will need to process still lower sulfur and, consequently, more costly grades of crude oil than they used in 1973. This cost differential of about 12 cents per barrel is clearly attributable to EPA's regulations.

Small "A"-type asphalt refineries are premised to process high-sulfur crude oil so they will not face relative crude price increases. However, in addition to asphalt and naphtha jet fuel, "A" plants manufacture a high-sulfur heavy distillate with physical properties intermediate between distillate and residual fuel oils. This material will not conform to EPA's sulfur content regulations. The cost estimate for desulfurizing this distillate was based on transporting it to a large

refinery for processing. This costs about 21 cents per barrel crude oil processed.

Net EPA cost is the cost of conforming to water, air and product quality regulations less the increased revenue received due to product price increases caused by EPA's regulations. There is a very large variation in water effluent control costs faced by these plants - from nil to 45 cents per barrel crude oil. (The costs reflect complete conformance to BATEA requirements.) About half of the simple "T"- and "A"-type plants will be net cost-advantaged by EPA's regulations. But, because of high lead-in-gasoline control costs, all "R"- and "C"-type plants will be net disadvantaged.

3. Refinery Cash Flows in the Absence of EPA's Regulations

The revenue and cost elements needed to derive cash income before tax ("cash flow" hereafter) for a refinery include product yields, product prices, cash operating cost, and crude oil cost. Product yield structures have been premised for the base version of the model expansion and for the four prototype small refinery configurations. Prices for products will be those required to justify industry expansion.

Cash flow estimates for the small refinery prototypes are:

Estimated Cash Income Before Tax For Small Refinery Prototype In 1983 In The Absence of EPA's Regulations
(1974 dollars per barrel crude oil processed)

	"T"	"R"	"C"	"A"
Base Expansion Cash Flow	1.84	1.84	1.84	1.84
Adjustments Relative to Base Expansion				
Product Revenue	0.22	0.43	0.66	(0.73)
Operating Cost	0.15	0.05	(0.10)	0.05
Crude Oil Cost-				
Sulfur	(0.73)	(0.73)	(0.73)	-
Metallurgy	(0.10)	(0.10)	(0.10)	-
Gravity	(0.10)	(0.10)	(0.10)	0.20
Small Refinery Cash Flow	1.28	1.39	1.47	1.36

4. Impact of EPA's Regulations on Small Refineries

No refineries will be forced to close because of EPA's regulations. This statement, of course, is an over-simplification for it ignores cases of physical infeasibility or extraordinary costs. It is possible that some of these exist. Nevertheless the protection afforded existing refineries by the inflation of refinery construction costs from 1970 to 1975 is more than sufficient to shield all but special-case refineries from serious harm by EPA's regulations.

None of the small refineries' cash income before tax is reduced by more than one-half by EPA's regulations. And the cash flow of the most affected plant is still about 70 cents per barrel of crude oil processed. If this refinery were to have an expected remaining life of 20 years, its capital value would be nearly one thousand dollars per daily barrel of stream day capacity. It is likely that the inevitable closures of certain of the older plants that are approaching the end of their normal economic life will be accelerated by EPA's regulations. Similarly the closure of plants whose viability is adversely affected by changes in crude oil supplies or customer requirements may also be accelerated.

5. Employment Effects

The 100 small refineries in the continental U.S. of 20 thousand barrels per day capacity or less have an aggregate capacity of approximately 800 thousand barrels per day and employ about 7,000 persons. Since no plants are expected to close solely because of the impact of EPA's regulations, the employment effect of these regulations is to increase employment by a small amount.

E. Sensitivity Analyses

1. Effect of Higher (and Lower) Capital Costs for EPA Investments

Total annual EPA-caused costs rise from 1.9 billion to 2.3 billion dollars in the 25 percent higher-, and drop to 1.4 billion in the 25 percent lower capital cost cases. Higher unit capital costs for conforming new refinery capacity to EPA regulations will cause higher per-barrel annual compliance costs, and (identically) higher EPA-caused price increases. So less new refinery capacity will be needed. For existing-in-1973 refineries the cost to conform to EPA's regulations will increase, but so will cost recovery.

There will be negligible change in the numbers of small refineries advantaged/disadvantaged by EPA's regulations. In other words, varying EPA capital estimates plus or minus 25 percent has no significant effect on the viability of the small refineries studied.

2. Effect of a Lower Level of Tariff Protection

The major effect of a lower level of tariff protection would be that no new refinery capacity would be constructed that is not now firmly planned. Therefore, the price increases necessary to justify EPA costs in such plants would not be forthcoming.

A tariff level 40 cents per barrel below the level needed to encourage expansion of EPA-conforming refinery capacity was assumed. This level of tariff would eliminate new refinery construction and lead to substantially lower cash income before tax for existing refineries.

At the lower level of tariff EPA's regulations would have no effect on prices in the U.S. market. This is because prices would be set by imported products not subject to EPA's regulations. So there would be no recovery of EPA costs. And there would be no volume effects of EPA's regulations.

At the base tariff level, EPA's regulations lead to an increase in cash flow to existing-in-1973 refineries of about eleven cents per barrel. At the lower tariff level the entire EPA cost of 28 cents per barrel would have to be absorbed. This is a substantial impairment of cash income but it is not so large as to force abandonment of any known plants, including small ones.

3. Effect of a Lower Price Differential Between High-Sulfur and Low-Sulfur Crude Oils

The cost of EPA's sulfur regulations are strongly influenced by the sulfur content price differential. The basic analysis used an implied differential of 86 cents per barrel per percent sulfur. A zero differential was chosen for the sensitivity analysis. Intermediate values can be adequately estimated by linear interpolation.

It was found that existing-in-1973 refineries are relatively advantaged by EPA's sulfur regulations. This is because percent yield of residual fuel oil and use of liquid refinery fuel are lower in these plants than in refinery capacity expansions. The competitive impact of EPA's regulations on small refiners is essentially independent of the sulfur price differential and hence of sulfur regulations.

4. Effect of Different Demand Elasticity Estimates

Per barrel costs of EPA's regulations are independent of elasticity. So EPA-caused price changes are also independent of elasticity estimates. Consequently, capital costs, annual costs, and cost recovery for existing-in-1973 refineries, and impacts on small refineries, are unaffected by changes in demand elasticity estimates.

Different elasticity estimates do have effects on the total EPA costs of new refinery capacity. Relative to the base analysis the effects of a more elastic demand response are to decrease product consumption, investment requirement for growth, and investment required to meet EPA's regulations. The effects

of a less elastic demand response are similar, but in the opposite direction; i.e., increased product consumption and investments.

5. Effect of Lower or Higher Crude Oil Prices

A three dollar per barrel reduction of crude oil price (from 12.75 dollars per barrel delivered to U.S. refineries to 9.75 dollars) would decrease the costs of EPA's regulations in the model expansion by about two cents per barrel crude oil processed (due to the lower value of refinery fuel). This results in trivially lower product prices. EPA costs to existing-in-1973 refineries would be slightly increased because some investments would become EPA-caused rather than profitable. Competitive impacts on existing-in-1973 small refineries would be about the same as at the base crude oil price.

Because price affects quantity demanded, a crude oil price of 9.75 dollars per barrel would require about twice the volume of new refinery capacity to be constructed during 1974/1983 as was needed at a 12.75 dollar price. So EPA-caused costs for new capacity would be twice those shown in the base case.

The effect of a one dollar per barrel crude oil price increase (to 13.75 dollars) would be consistent with the price decrease results, but in the opposite direction. That is, the EPA impact on existing-in-1973 refineries would be almost the same as at 12.75 dollars per barrel, but capital requirements for expansion capacity would be less.

A crude oil price increase of five dollars per barrel (to 17.75 dollars) would have a profound impact on the petroleum refining industry. Product consumption in 1983 would be decreased so that there would be some retirements of existing-in-1973 facilities. In that event prices would reflect the cash-out-of-pocket costs of the least efficient refiner who was needed to balance

the market - all higher cost plants would close. In such an economic climate the only EPA cost recovery that could occur would come from the cash operating cost increase experienced by the least efficient refiner who was able to stay in business. Essentially the entire capital costs of EPA's investments would have to be absorbed by the industry.

A 15.75 dollars per barrel price (three-dollar increase) could produce intermediate effects. The effect would be to require additional refining capacity to manufacture distillate fuel oil, jet fuel and petrochemical feedstocks, coupled with a reduction in the output of gasoline and residual fuel oil in existing refineries. At a crude oil price of 12.75 dollars per barrel, the EPA cost of manufacturing unleaded gasoline in new refineries is nil. Consequently, at that crude oil price, existing-in-1973 refineries are forced to fully absorb the cost of converting to unleaded gasoline. So a higher crude oil price will not further disadvantage existing plants on this account. The cost of controlling sulfur content of residual fuel oil and refinery liquid fuel would be only slightly increased by crude oil prices higher than 12.75 dollars per barrel crude oil. Net, the impact of EPA's regulations on existing-in-1973 refineries would be about the same at crude oil prices of 15.75 and 12.75 dollars per barrel.